Faculty of Engineering

STORM RAINFALL ANALYSIS FOR UPPER RAJANG RIVER CATCHMENT

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For my beloved Family

Acknowledgment

I would like to first and foremost thank my parents for their continual and unwavering support throughout this study. I would also like to express my gratitude to my supervisor, Assoc. Prof. F. J. Putuhena, for his guidance and mentoring. My heartfelt thanks also go out to the Director Of DID Sarawak, Deputy Director of DID Sarawak, Mr Thomas Lau, whose patience and willingness to help which I can not do without, and employees of DID Sarawak for their assistance in carrying out this study. Not to forget, the staff of JKR Sarawak for their assistance and help. Finally, I would like to thank everybody else who are directly or indirectly involved in contributing to the success of this study.

Abstract

There are numerous examples throughout history where settlements, and even entire civilizations were damaged due to rampaging floods which were caused by heavy rains. Rainwater, in small amounts, are necessary as a water source, yet can cause flash floods and landslides in large amounts. Therefore, proper planning need to be carried out to avert such catastrophes, which include preparing adequate drainage, stormwater management and flood control projects. Sarawak, with its many and wide areas of catchments, is able to make use of rainfall through generation of hydroelectric power. The Upper Rajang catchment, being one of the largest river basins, has great potential in this respect. Usage of Department of Irrigation (DID) Sarawak supplied temporal profiles and IDF curves do not yield satisfying results when used in calculations in designing a Design Storm for large hydraulic structures, such as a barrage or a dam, therefore, a study was warranted in order to overcome this problem. The storm characteristics such as the temporal and spatial profiles are necessary in order to produce a Design Storm. This study utilizes a threshold in order to select a sufficient number of storms that is gathered from the historical data. The spatial profiles are generated from the daily rainfall records, whereas a temporal profile study was carried out using the hourly data, each collected from automatic and manual recording apparatus. A relationship between storm depth and area covered for high recorded storms was established. The study also points out differences observed between the temporal profiles available from historical data, and those provided by the DID guidelines.

Abstrak

Kesan-kesan buruk air boleh diperhatikan melalui sejarah, di mana penempatan malahan tamadun dirosakkan oleh banjir yang disebabkan oleh hujan berlebihan. Air hujan yang sedikit sesuai dijadikan sumber air tawar, namun sekiranya dalam jumlah yang terlalu besar, boleh menagkibatkan banjir kilat. Oleh itu, perancangan yang rapi harus diambil bagi mengelakkan kesan negatif oleh banjir, termasuklah pengairan, pengurusan air hujan dan projek pengawalan banjir. Sarawak mempunyai kawasan tadahan air yang besar dan banyak, adalah berpotensi dari segi penjanaan tenaga hidroelektrik. Kawasan tadahan Rajang Atas merupakan salah sebuah kawasan tadahan yang terbesar, mempunyai potensi yang cerah sebagai sumber penjanaan tenaga hidroelektrik. Penggunaan "IDF curve" dan profail masa yang disediakan oleh Jabatan Pengairan Sarawak tidak memenuhi keperluan bagi menyediakan "Design Storm", oleh itu sebuah kajian perlu bagi mengatasi kekangan ini. Kajian ini menggunakan nilai had bagi membolehkan jumlah ribut yang didapati daripada data tahunan adalah mencukupi. Profail masa dihasilkan daripada data setiap jam, manakala profail kawasan dihasilkan daripada data hujan harian. Suatu hubungan di antara kedalaman hujan dengan kawasan yang diliputi telah disediakan. Kajian ini juga menunjukkan perbezaan di antara profail daripada data yang didapati daripada data hujan sebenar berbanding profail yang disediakan oleh JPS.

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Notation

IDF	-	Intensity-Duration-Frequency Curve
ARI	-	Average Recurrence Interval
DID	-	Drainage and Irrigation Department
MMS	-	Malaysian Meteorological Service
mm	-	millimeter
mm/hr	-	millimeter per hour
PMP	-	Probable Maximum Precipitation
in	-	inch
km	-	kilometer

Chapter 1

Introduction

1.1.1 Introduction

Storm characteristics vary from each storm to the next, which means that the effects on catchment areas and ultimately river flows are different. Therefore, a study on the characteristics of the aforementioned storms are required to yield a Design Storm – a synthetically derived (i.e. derived from calculations and not recorded actual storms) rainfall event with the characteristics such as annual probability of exceedance or recurrence interval, rainfall distribution, rainfall depth, computational time interval, spatial distribution, and temporal distribution. The exceedance probability is selected based on the particular application, in this case for the un-gauged river. The rainfall depth of a specified exceedance frequency and rainfall duration is determined from an IDF (Intensity-Duration-Frequency) relationship.

The Design Storms calculated would then be used to determine a Design Flood, a particularly important aspect in the un-gauged rivers. Rainfall data is used to derive the flood frequency; however if recorded data is unavailable, the annual maximum daily rainfall is used. The rainfall data is recorded by the Department of Irrigation and Drainage Department (DID) Sarawak, and from the data collected, there is no information on the average characteristics of the annual maximum rainfall. The storm characteristics -area coverage, duration and profile- are then needed to be determined.

1.1.2 Objectives

The objective of this study therefore consists of:

a. To review the rainfall data collected in the Upper Rajang Catchment area.
b. To study the storm characteristics (Duration, Temporal Profile and Area Coverage) from historical data, with the emphasis on Area Coverage
c. To discuss the storm characteristics from historical data for further application in producing Design Storm.

In the interest of creating a more conventional Design Storm, the storms studied will be limited to the daily rainfall recorded from 0800 hrs to 0800 hrs (+8 GMT) with the exceedance of a threshold amount (e.g. 400 mm/day)

1.2 Background (General Overview) of Storm Rainfall

1.2.1 Rainfall Definition

Rainfall is a form of precipitation, together with snow, sleet, hail and mist. The main source of precipitation is the sea, with evaporation taking place on the surface. The water vapour is absorbed in the air streams moving across the sea's surface. As the water laden air keeps the water vapour absorbed, it will then come back down as precipitation after cooled to below dew-point temperature – known as either convective precipitation, orographic precipitation or cyclonic and frontal precipitation.

Being the main source of rivers, rainfall influences all stormwater studies and designs. Therefore, in order to be able to prepare satisfactory drainage and stormwater projects, a good understanding of rainfall processes and appreciation of the importance of the rainfall design data is required.

1.2.2 Storm Characteristics and Design Storm

Rain storms differ in form, with precipitation varying from 0 mm to over 700 mm per day, and duration as well. A light storm can deliver 20 mm of rain, whereas an intense storm can deliver the same amount in just an hour. Therefore, the runoff characteristics will also change with the storm characteristics.

Storm events can be divided into 2; actual storms and design storms. An actual storm event is a series of rainfall measured over time at rain gages, and rainfall analysis is based on these records.

A design storm, on the other hand, is not an actual measured storm- it may have never occurred nor may it ever occur- but is a rainfall hyetograph with preselected characteristics. However, most design storms have the average characteristics of previous recorded storms to be able to better predict the average characteristics of future storms. Most, if not all hydrologic designs are based on the design storm approach.

1.2.3 Storm Event

Return period (also known as frequencies) are assigned to rainfall events on the basis of a number of parameters, such as total volume, average intensity, peak intensity, duration or inter-event time. The rainfall series must first be separated into a series of discrete, independent events according to the parameters. After this is done, the rainfall series may be ranked by volume or any parameter, and a conventional frequency analysis may then be performed.

For ease of computation, a statistical measure is usually employed to separate independent storm events. A Minimum Inter-event Time (MIT) is defined so that rainfall pulses separated by a time less than this value is considered as part of the same event.

1.2.4 Effects of Storm Rainfall

Problems result when rainfall occurs at extreme volumes or rates. High rainfall rates of rainfall on small urban watersheds may overcome the existing water drainage facilities and cause floods. Besides that, high rainfall rates can also cause severe damage to crops. Finally, high rainfall rates can also contribute to increased surface runoff into rivers, which in turn may cause to rivers to overflow and flood low-lying areas.

1.3 Sarawak and Upper Rajang River Basin Conditions

1.3.1 Climate and Physical Conditions

Sarawak, the largest state in Malaysia, is blessed with a tropical climate and is outside volcanic, tornado and severe drought belts (See Figure 1: Location of Sarawak in Malaysia). Most towns in Sarawak are located on coastal alluvium; however, most of Sarawak consist of limestone which are found in the interiors. Sarawak, as is the rest of Malaysia, is warm and humid throughout the year, which can be seen through the average annual rainfall of more than 2500 mm. Most storms occurring in Sarawak is generated by the Northeast Monsoon, which occurs from November to March (Malaysia Meteorogical Service). The Southwest Monsoon, which happens in May to September, on the other hand, carries very little rain to Sarawak.

Figure 1: Location of Sarawak in Malaysia

1.3.2 River Basins in Sarawak State

In order to facilitate and encourage rapid development, Sarawak has been divided into 21 river basins namely, Kayan, Sg Sarawak, Samarahan, Sadong, Lupar, Krian, Saribas, Oya, Mukah, Balingian, Tatau, Kemena, Similajau, Suai, Sibuti, Niah, Baram, Limbang, Lawas, Trusan and Upper and Lower Rajang river basins. The location of the river basins are shown in Figure 2: River Basins in Sarawak.

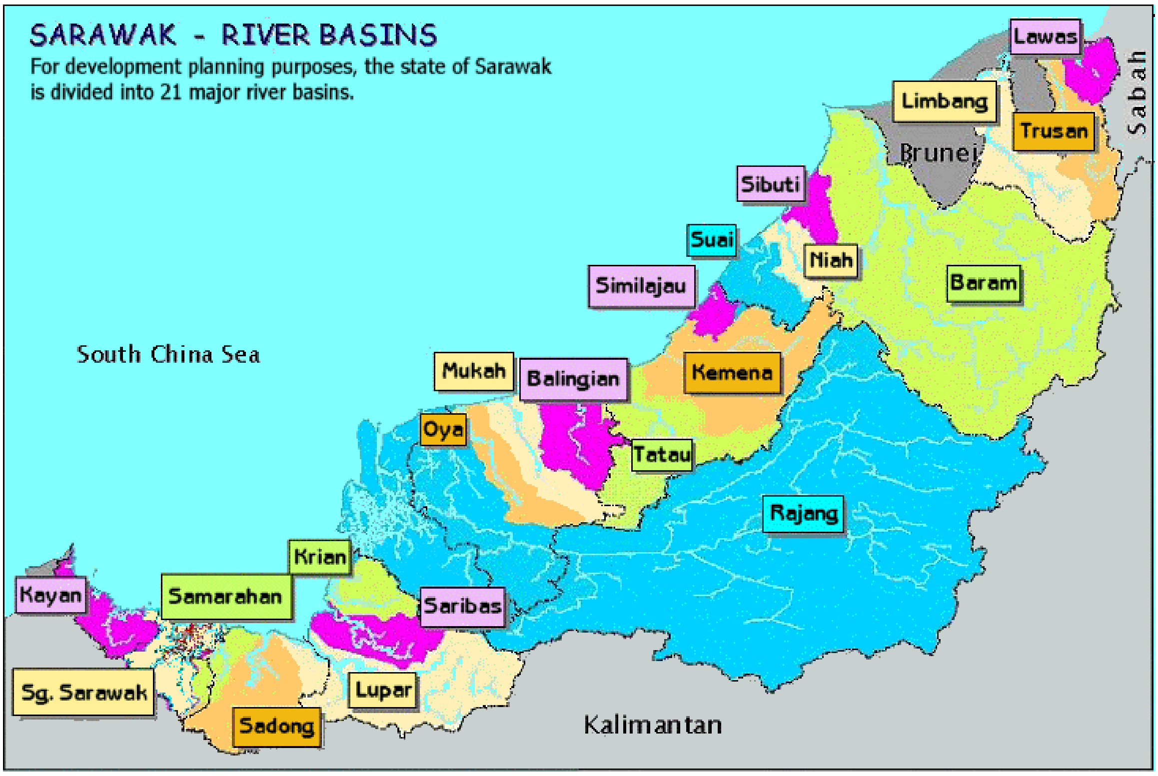

Figure 2: River Basins in Sarawak

1.3.3 Rainfall Stations at Upper Rajang Basin

Due to the large size of the Rajang river basin, the authorities decided to divide the catchment area into two, namely the Upper and Lower Rajang Basins. Both basins cover a total area of 47880 square kilometers.

The Upper Rajang Basin is located in the Seventh Division (now known as Kapit). The main river of the catchment is Batang Rajang, which has a combined length of 760 kilometers and is the longest river in Sarawak. The Upper Rajang Basin has 29 rainfall stations. The locations of the stations can be seen in Figure 3: Location of Upper Rajang Basin Rainfall Stations.

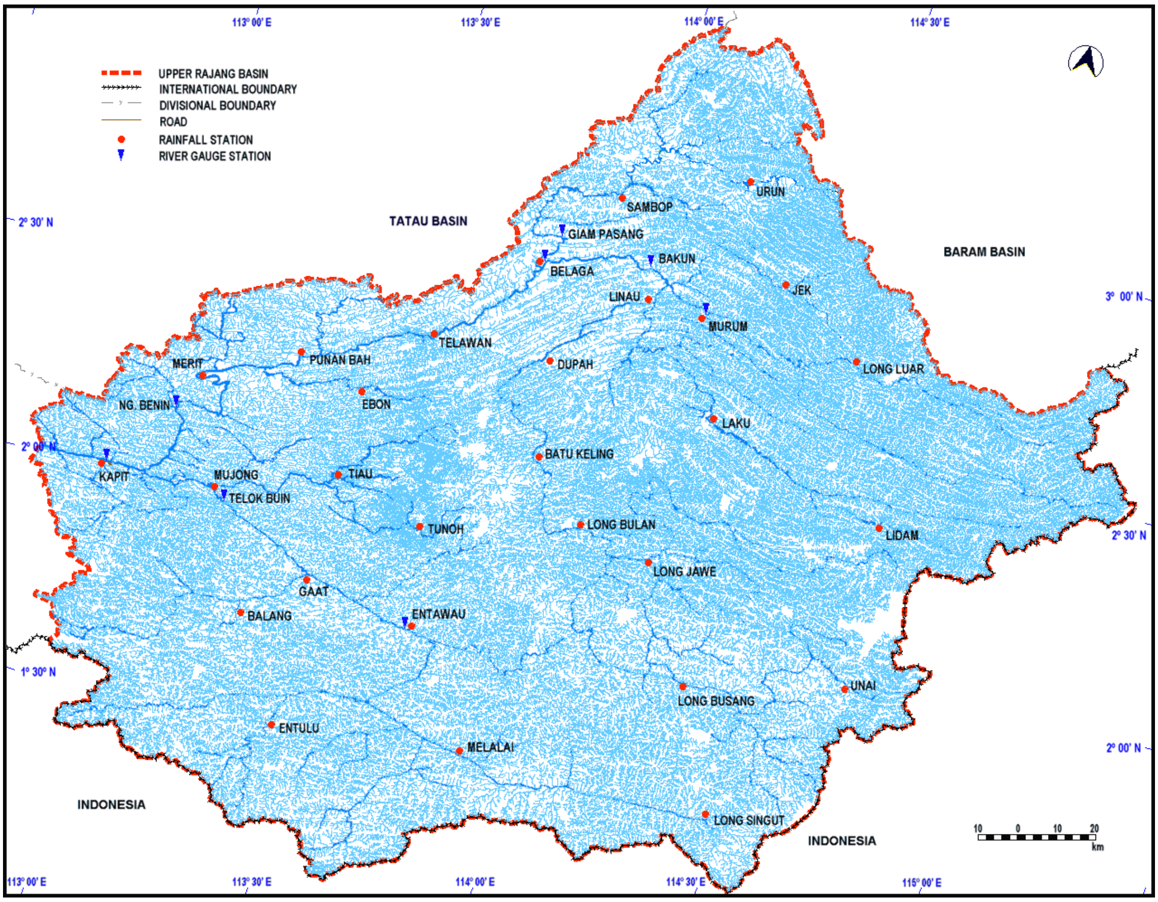

Figure 3: Locations of Rajang Basin Rainfall Stations

Chapter 2

Literature Review

2.1 Forms of Precipitation

Atmospheric moisture in the form of vapour originates from large bodies of water, namely oceans and seas. Water vapour evaporated are absorbed in the air streams moving across the surface, and come back down to earth due to condensation. The water vapour comes back down in a number of forms, namely *rain, snow, drizzle, glaze, sleet, hail* and *dew.* Fog and frost, despite involving water vapour, is not considered as precipitation since the water moisture is suspended in the atmosphere and not coming down to earth. Rain happens when the precipitation reaches the earth surface in the form of droplets of water. Sizes of raindrops range from 0.5 to 6 mm, while larger sizes break up while traveling through the air. Rain can be classified according to the intensity; heavy (up to 2.5mm/h), moderate (2.5 mm/h to 7.5 mm/h), and heavy (over 7.5 mm/h). Snow is rain which has been frozen into ice in the atmosphere and occurs in countries of temperate climate due to the low temperatures during winter.

2.2 Types of Precipitation

In order for water to condense, the water molecules first need to cling to nuclei in the atmosphere – in the current age of rapid industrialization, there is no lack of potential nuclei comprising of dust and carbon particles released during combustion. Adiabatic cooling through lifting facilitates condensation in the atmosphere.

Precipitation can be classified according to the lifting factors, namely i) convective ii) orographic iii) cyclonic and iv) thunderstorms.

2.2.1 Convective Precipitation

Convective precipitation, also known as thermodynamic precipitation, happens due to lifting of water vapour from the surface into the atmosphere. This lifting is due to the water vapour itself lifting after absorbing a certain amount of heat, rather than carried directly by the wind (such as in orographic precepitation). As the water vapour is carried ever higher, it is cooled to below the dew point, thereby releasing latent heat (approximately 539 cal/g) as the water vapour undergoes condensation. This heat in turn causes further heating of the air, making the air mass move upwards. This starts a chain reaction, causing more and more water vapour to be carried up into the atmosphere. When the amount of condensation reaches a certain point, it will come back down as rain. This form of precipitation is mainly found in the equatorial zone, since it requires large amounts of water vapour in the air, and is of extremely limited aerial extent. Finally, normally convective precipitation is accompanied by lightning and thunder while falling at a high rate. Please see Figure 3 for a visual representation of the process.

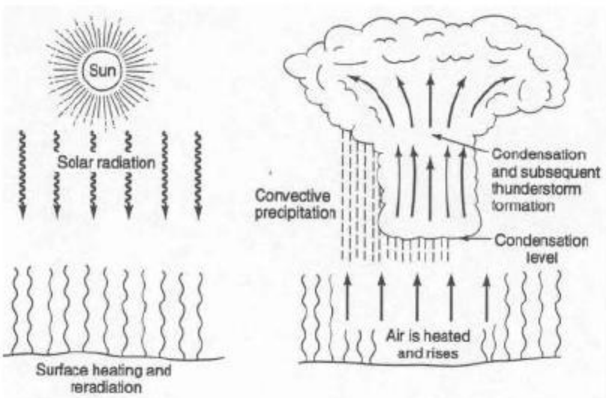

Figure 4: Components of convective precipitation

2.2.2 Orographic Precipitation

Orographic precipitation is also known as stratiform, relief or dynamic precipitation. Like convective precipitation, it is initiated by the lifting of water vapour from the surface to the atmosphere. However, it differs in that it does not require instability of the water vapour (i.e. the water vapour does not need to absorb heat to rise by itself) and relies mainly on the other two factors, namely moisture and lift. Anabatic wind coming from large bodies of water such as the seas and oceans, encounter hills, ranges and other mountainous terrain at the sea side. Therefore, the wind would rise as it traverses the geography. The rising action of the moisture-laden wind causes the water vapour being carried to become cooler, undergoing condensation and forming clouds. As more water vapour gets collected by the cloud, it will reach a limiting point, and would then come back down as rain. This phenomenon would normally see that one side of hills and mountains experiencing rain while the other side experiences none. Finally, unlike convective precipitation, orographic precipitation is not accompanied by thunder and lightning, and falls at a gentler rate. (Please to Figure 5)

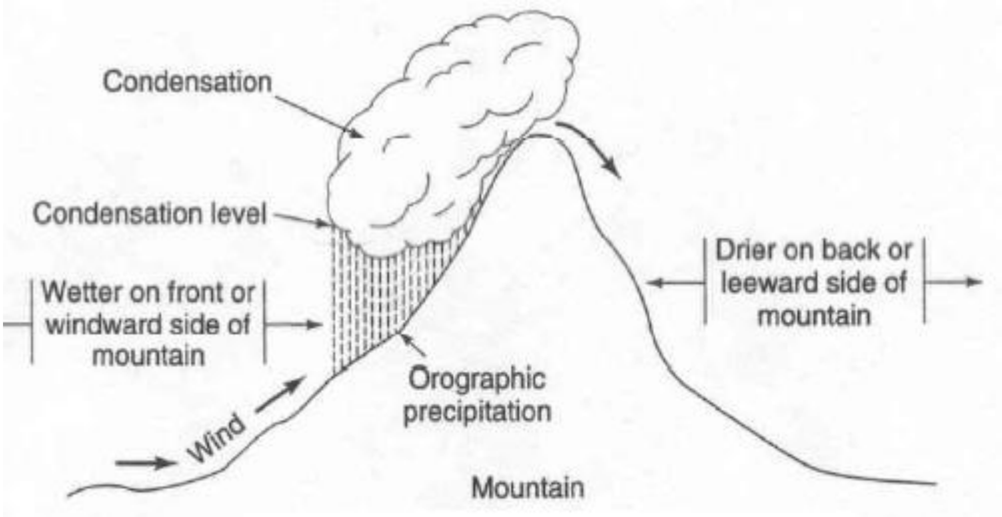

Figure 5: Components of orographic precipitation

2.2.3 Cyclonic Precipitation

Cyclones, infamous due to their destructive capabilities, have humble beginnings. It results from having two fronts (warm and cold) colliding into each other. These two fronts are in turn created by unequal heating of the earth's surface.

On the basis of the nature of the meeting of fronts, cyclonic precipitation can be further classified into two; frontal and non frontal. Frontal precipitation is when warm air is pushed above the cold air at the contact point. Non-frontal precipitation, on the other hand, occurs when the air is lifted through the covergence of the inflow into a low pressure area. This form of precipitation creates large scale tropical cyclones, with a very low pressure in the middle of the cyclone (which is known as the eye), and creates havoc due to high wind speeds surrounding the eye. The cyclone derives its energy from sea vapour, therefore it will slowly dissipate at it crosses over land. Curiously, cyclones in the northern hemisphere move in anti-clockwise direction, whereas cyclones in the southern hemisphere move in the opposite direction. Cyclones bring large amounts of rain, typically lasting from a few hours to a few days. The components of cylconic precipitation can be seen in Figure 6.